



White Paper:
H.264 / AVC Intra Prediction

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Prediction of Intra Macroblocks

1 Introduction

This document describes the methods of predicting intra-coded macroblocks in an H.264 video compression codec.

If a block or macroblock is encoded in intra mode, a prediction block is formed based on previously encoded and reconstructed (but **un-filtered**) blocks. This prediction block P is subtracted from the current block prior to encoding. For the luminance (luma) samples, P may be formed for each 4x4 sub-block or for a 16x16 macroblock. There are a total of 9 optional prediction modes for each 4x4 luma block; 4 optional modes for a 16x16 luma block; and one mode that is always applied to each 4x4 chroma block.

2 4x4 luma prediction modes

Figure 1 shows a luminance macroblock in a QCIF frame and a 4x4 luma block that is required to be predicted. The samples above and to the left have previously been encoded and reconstructed and are therefore available in the encoder and decoder to form a prediction reference. The prediction block P is calculated based on the samples labelled A-M in Figure 2, as follows. Note that in some cases, not all of the samples A-M are available within the current slice: in order to preserve independent decoding of slices, only samples within the current slice are available for prediction. DC prediction (mode 0) is modified depending on which samples A-M are available; the other modes (1-8) may only be used if all of the required prediction samples are available (except that, if E, F, G and H are not available, their value is copied from sample D).

The arrows in Figure 3 indicate the direction of prediction in each mode. For modes 3-8, the predicted samples are formed from a weighted average of the prediction samples A-Q. The encoder may select the prediction mode for each block that minimizes the residual between P and the block to be encoded.

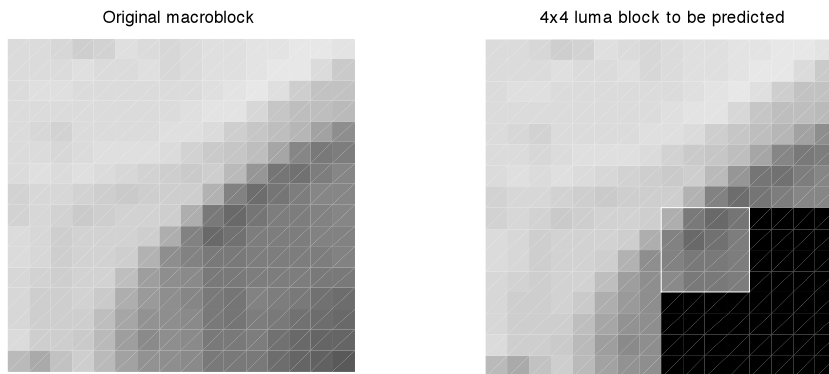


Figure 1 Original macroblock and 4x4 luma block to be predicted

M	A	B	C	D	E	F	G	H
I	a	b	c	d				
J	e	f	g	h				
K	i	j	k	l				
L	m	n	o	p				

Figure 2 Labelling of prediction samples (4x4)

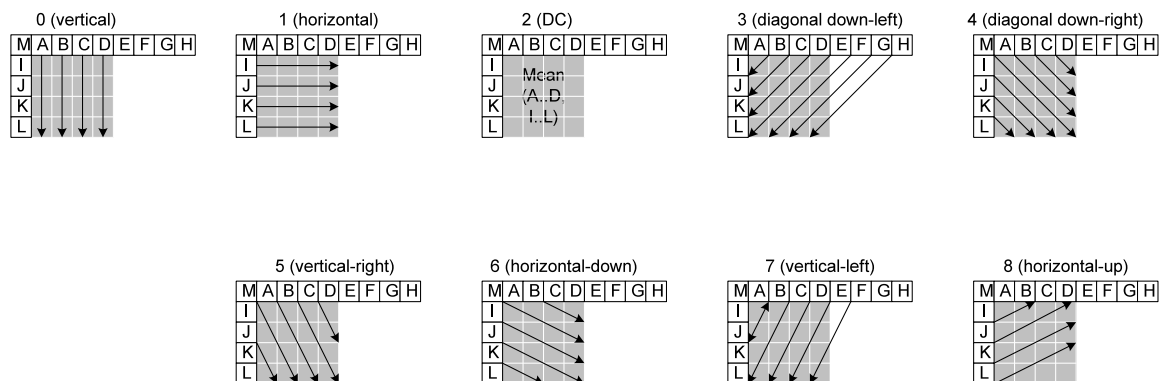


Figure 3 4x4 luma prediction modes

Example: The 9 prediction modes (0-8) are calculated for the 4x4 block shown in Figure 1. Figure 4 shows the prediction block P created by each of the predictions. The

Sum of Absolute Errors (SAE) for each prediction indicates the magnitude of the prediction error. In this case, the best match to the actual current block is given by mode 7 (vertical-right) because this mode gives the smallest SAE; a visual comparison shows that the P block appears quite similar to the original 4x4 block.

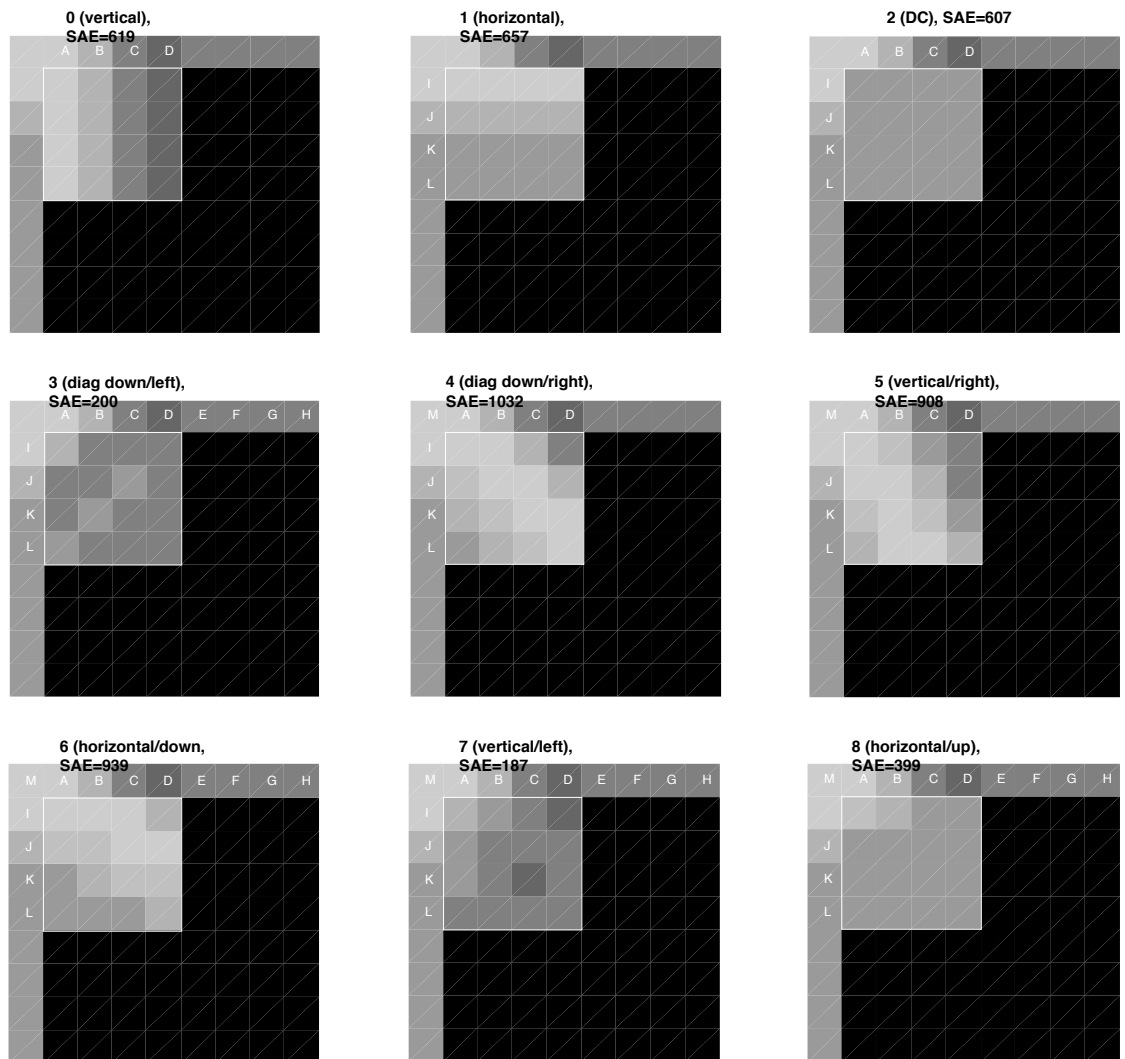


Figure 4 Prediction blocks P (4x4)

3 16x16 luma prediction modes

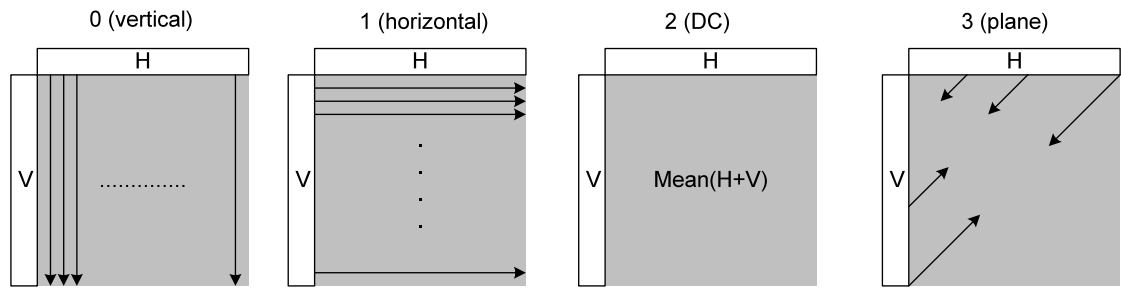
As an alternative to the 4x4 luma modes described above, the entire 16x16 luma component of a macroblock may be predicted. Four modes are available, shown in diagram form in Figure 5:

Mode 0 (vertical): extrapolation from upper samples (H).

Mode 1 (horizontal): extrapolation from left samples (V).

Mode 2 (DC): mean of upper and left-hand samples (H+V).

Mode 4 (Plane): a linear "plane" function is fitted to the upper and left-hand samples H and V. This works well in areas of smoothly-varying luminance.



H.264 Intra 16x16 prediction modes (all predicted from pixels H and V)

Figure 5 Intra 16x16 prediction modes

Example:

Figure 6 shows a luminance macroblock with the previously-encoded samples at the upper and left-hand edges. The results of prediction (**Figure 7**) indicate that the best match is given by mode 3. Intra 16x16 mode works best in homogeneous areas of an image.

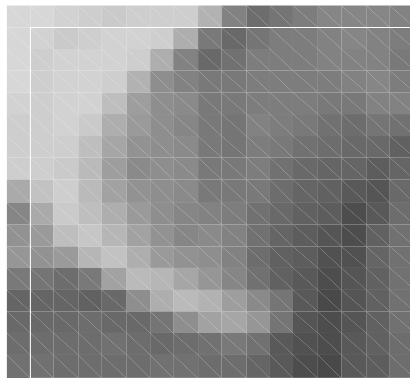


Figure 6 16x16 macroblock

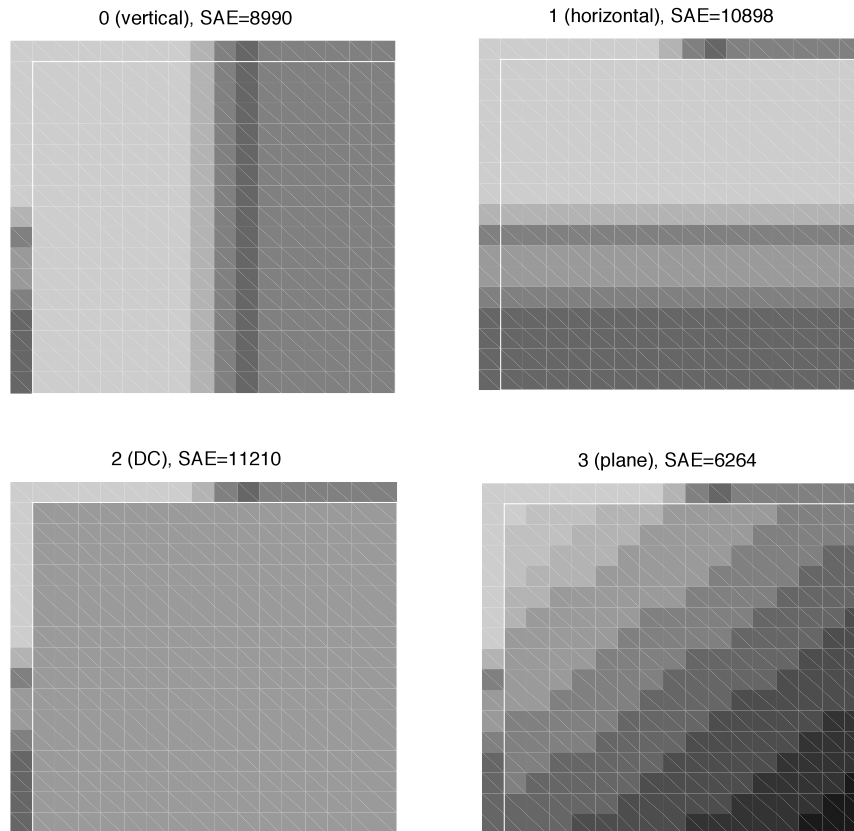


Figure 7 Intra 16x16 predictions

4 8x8 chroma prediction mode

Each 8x8 chroma component of a macroblock is predicted from chroma samples above and/or to the left that have previously been encoded and reconstructed. The 4 prediction modes are very similar to the 16x16 luma prediction modes described in section 3 and illustrated in Figure 5, except that the order of mode numbers is different: DC (mode 0), horizontal (mode 1), vertical (mode 2) and plane (mode 3). The same prediction mode is always applied to both chroma blocks.

Note: if any of the 8x8 blocks in the luma component are coded in Intra mode, both chroma blocks are Intra coded.

5 Encoding intra prediction modes

The choice of intra prediction mode for each 4x4 block must be signalled to the decoder and this could potentially require a large number of bits. However, intra modes for neighbouring 4x4 blocks are highly correlated. For example, if previously-encoded 4x4 blocks A and B in Figure 8 were predicted using mode 2, it is likely that the best mode for block C (current block) is also mode 2.

For each current block C, the encoder and decoder calculate the `most_probable_mode`. If A and B are both coded in 4x4 intra mode and are both within the current slice, `most_probable_mode` is the minimum of the prediction modes of A and B; otherwise `most_probable_mode` is set to 2 (DC prediction).

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The encoder sends a flag for each 4x4 block, `use_most_probable_mode`. If the flag is "1", the parameter `most_probable_mode` is used. If the flag is "0", another parameter `remaining_mode_selector` is sent to indicate a change of mode. If `remaining_mode_selector` is smaller than the current `most_probable_mode` then the prediction mode is set to `remaining_mode_selector`; otherwise the prediction mode is set to `remaining_mode_selector+1`. In this way, only 8 values of `remaining_mode_selector` are required (0 to 7) to signal the current intra mode (0 to 8).

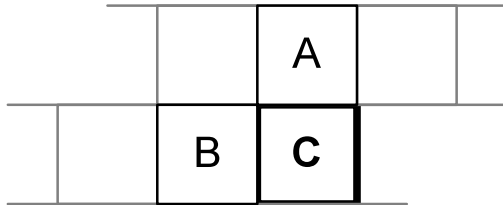


Figure 8 Adjacent 4x4 intra coded blocks

Further reading

Iain E Richardson, "The H.264 Advanced Video Compression Standard", John Wiley & Sons, 2010.

About the author

Iain Richardson wrote the books on H.264 video compression : see <http://vcodex.com/h264book/>. A founder of OneCodec, he is changing the way video coding works.

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